RENEWABLE RESOURCE SUPPLY CURVE REPORT

New England States Committee on Electricity

January 2012

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available at www.nescoe.com

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I. INTRODUCTION: REGIONAL RENEWABLE ENERGY SUPPLY CURVE ANALYSIS

In July 2011, the New England's Governors expressed their interest in continuing to explore the potential for joint or separate but coordinated competitive renewable power procurement as a means to enable the states to achieve their clean energy objectives at the lowest all-in cost to consumers.[1] In this context, "all-in" costs means the sum of costs required to construct and operate renewable generation resources *plus* the cost of transmission upgrades necessary to achieve the preferred level of energy integration or deliverability.

Accordingly, to better inform state policymakers' consideration of possible ways forward to meet the region's clean energy and environmental objectives, the New England States Committee on Electricity (NESCOE) developed an indicative regional renewable resource "supply curve". In broad terms, the "supply curve" suggests the cumulative amount of renewable energy that would be available for purchase as the price for renewable energy increases.

> Costs that would emerge in a competitive procurement process would likely be meaningful lower than the base costs presented here due to the use of conservative assumptions. The magnitude of such reductions could range from $33 to $68 MWh.

NESCOE's supply curve analysis was limited by several parameters. First, it looked at resources available and their costs in two years, 2016 and 2020. The point of the two study years was to illustrate the range and mix of wind resources that may be available in the relative near-term and over the next decade. Second, it focused on resources in New England and in New York.[2] Third, the conservative assumptions used in the base case analysis (*e.g.,* the assumed unavailability of federal financial incentives) means that actual costs for actual projects will likely be less than the base case costs. Finally, the analysis only evaluated wind resources due to

[1] New England Governors' Resolution is at this link: http://www.nescoe.com/uploads/NEGC_Coord_Procure_Res._.pdf

[2] NESCOE did not include Canadian resources in the supply curve analysis due to its technical consultant's counsel concerning the significant disparities in data between regional and Canadian resources. Because resources from Canada are an important part of the region's supply mix, NESCOE has invited the Canadian Electricity Association to provide a comparable supply curve analysis of its wind resources for consideration by New England's policymakers. See, http://www.nescoe.com/uploads/CEA_Letter_11.20.11.pdf

the region's widespread potential for wind development. This corresponds to the predominant resource type that responded to NESCOE's Request for Information from renewable developers in 2011 and the resources ISO-New England focused on in the technical analysis underlying the *New England Governor's Renewable Energy Blueprint*.[3] The focus on wind for purposes of this analysis does not indicate any preference for wind resource relative to myriad other renewable resources that are available in the region to help New England meet its clean energy objectives.

As noted earlier, the analyses reflect several conservative assumptions concerning generation costs. For example, the generation analyses assumed: ***no*** federal tax incentives will be available for future wind projects; interest rates consistent with ***normal*** economic growth; and, the use of ***historical*** hub heights for on-shore wind projects. Changing ***any one*** of these assumptions to be less conservative could materially decrease the expected costs. Accordingly, the cost data is directionally indicative; its greatest use is to provide a sense of the relative costs of various resources.

Given the very conservative base case assumptions, actual costs that would emerge from a competitive procurement process would likely be meaningfully lower than the base costs considered herein. The magnitude of such reductions could range from $33 to $68 MWh, with the largest reductions occurring at on-shore wind resources that could most greatly benefit from the use of taller towers. The upper bound on the potential cost reduction of $68 per MWh consists of three components: $10 (lower interest rates) + $23 (continuation of federal incentives) + $35 (use of higher hub heights from some on-shore supply blocks).

To develop a supply curve, NESCOE retained two consultants to provide independent analysis. Sustainable Energy Advantages, LLC (SEA) provided NESCOE with data and analysis regarding the region's potential wind energy resources and the generation costs for those resources. RLC Engineering (RLC) provided NESCOE with information about cost of, and limits to, transmission projects that would help integrate the output of wind generation projects located in certain geographic regions.

[3] ISO-NE's *Renewable Scenario Development Analysis* is at this link: http://www.nescoe.com/uploads/2009_Economic_Study_Final_Report.pdf

This Executive Summary reviews, primarily through illustrative graphs and tables: 1) SEA's and NESCOE's analyses of wind generation and their costs; 2) RLC's transmission analyses; and, 3) NESCOE's additional analysis that combined (a) the supply and generation cost data developed by SEA and (b) RLC's transmission related findings.

II. OBSERVATIONS: REGIONAL RENEWABLE SUPPLY CURVE ANALYSIS

- New England's total potential for wind energy production is sufficient to readily meet regional renewable energy goals.[4] Possible imports from New York could increase the potential regional supply even further. These findings are consistent with the results of NESCOE's 2010 Request for Information from renewable energy developers.

- These preliminary analyses provide *directionally indicative* costs for energy from various wind resources. For any particular project developed at a particular point in time, the actual cost of energy from that resource will be determined by market conditions prevailing at that time. However, these indicative cost results are useful in suggesting the types of wind resources that may be most likely to help meet regional renewable energy goals at the lowest overall cost, and in identifying the key issues that determine the mix of wind resources with the lowest "all in" costs.

- *If* there were no transmission constraints on the existing transmission system, on-shore wind generation located in Maine would provide the majority of wind energy with the lowest generation-related costs. For example, in 2016, 72% of the lowest-cost incremental energy required to meet regional renewable energy goals would come from on-shore generation in Maine. Such generation in Maine would supply approximately 5400 GWh/year out of total regional need of about 7500 GWh/year in 2016.

- However, the existing transmission system is not capable of supporting such an increase in wind generation in Maine. Transmission studies by RLC identified potential transmission upgrades in northern New Hampshire and western Maine that could support substantial increases in wind generation in those areas. The cost of those upgrades and

[4] In this memo, the term "regional renewable energy goals" is applied to the collective Renewable Portfolio Standards ("RPS") established for Connecticut, Maine, Massachusetts, New Hampshire and Rhode Island, and the renewable energy goals for Vermont. As noted herein, these analyses focused on wind energy resources that could be developed in New England and New York.

their timing could significantly affect the mix of wind resources with the lowest total costs in 2016 and 2020.

- Specifically, off-shore wind resources in New England and wind imports from New York may require less investment in transmission upgrades than on-shore wind projects in northern New England, depending on the region's preferred level of "wind integration". If so, and if the cost of on-shore wind in northern New England reflects at least some of the higher costs of the network upgrades required to integrate that on-shore energy in the desired manner, then by 2020, off-shore wind and imports from New York could become the marginal renewable energy sources for the region, and could begin to contribute towards regional renewable energy goals.

- Thus, a key issue for policy makers' consideration is *the preferred standard for integrating new wind resources.* A "REC Only"[5] integration standard - one that only requires incremental wind energy to displace non-renewable energy but does not require that such incremental renewable energy be delivered to major load centers - may lead to the mix of wind resources described later in this report. A "REC Plus" integration standard – *e.g.,* a requirement that new wind resources meet ISO-NE's interconnection standard for capacity integration and/or that the energy from such resources be deliverable to major New England load centers - might lead to substantially different mixes of wind resources, as the relative total costs of different resources could change substantially. A REC Plus integration standard would require greater investment in transmission but may also yield greater energy market benefits.[6]

- ISO-NE's current interconnection process would not support an efficient and effective coordinated renewable procurement process that used a REC Plus integration standard. A REC Plus integration standard would likely require significant changes to the

[5] The term "REC Only" denotes that the incremental resources merely needs to contribute to the total supply of Renewable Energy Credits – RECs – available to meet regional renewable energy goals

[6] In reality, the optimal level of energy integration may vary among specific projects, since the transmission costs for, and market benefits from, achieving different levels of energy integration for any particular project will be project-specific.

interconnection queue process before one or more states could undertake an efficient competitive coordinated renewable procurement process.

III. WHAT THE SUPPLY CURVE ANALYSIS IS *NOT*

The supply curve analysis is intended to provide high-level indicative cost information to policy makers about various wind resources. As such, the supply curve analysis does not provide cost data that could support decisions with respect to specific wind projects, for several reasons. First, the analyses are based on wind energy resource data, not on specific cost information about identified projects. The market will reveal actual project costs. Second, the analyses are based on generation and transmission costs developed pursuant to high-level assumptions, any one of which may prove to be wrong over time with the benefit of hindsight. Finally, these analyses did not consider the benefits of any projects with respect to the regional capacity and energy markets.

In sum, this analysis is:

- Not an expression of interest in certain types or locations of renewable resources relative to others;
- Not a regional resource or transmission plan or recommendation;
- Not a projection regarding the actual costs of specific resources or projects;
- Not a recommendation or suggestion to develop any specific resource, group of resources, or transmission upgrades; and,
- Not an estimate of the benefits of any specific resources or projects.

IV. LOOK BACK: NEW ENGLAND'S EXPLORATION OF COORDINATED RENEWABLE POWER PROCUREMENT

In the fall of 2009, New England Governors adopted the *New England Governors Renewable Energy Blueprint.*[7] The Blueprint included technical analysis conducted by ISO-NE that identified the significant renewable resources located in and around the region and policy

[7] The Blueprint is available at this link: http://www.nescoe.com/uploads/September_Blueprint_9.14.09_for_release.pdf

analysis that identified the potential for the New England states to coordinate competitive renewable power procurement and to better coordinate siting of interstate transmission facilities.

In mid-2010, in response to the New England Governors' request by Resolution, NESCOE provided the New England Governors a *Report on Coordinated Renewable Procurement*[8]. The Report identified potential coordination mechanisms and preliminary contractual terms and conditions.

In early 2011, NESCOE conducted a market survey of renewable resources under development by collecting information from renewable project developers in response to a *Request for Information* (RFI). The RFI identified: 1) approximately 4,700 MW of new renewable resources that could serve customers by 2016, 90% of which was wind, with 50% of the wind capacity located in Maine[9]; and 2) several transmission proposals that generally corresponded to the generation responses.[10] To encourage responses, the RFI did not request proprietary cost information.

In 2011, NESCOE also formed an Interstate Transmission Siting Collaborative to consider means to better coordinate siting processes for interstate transmission projects. Recently, the Collaborative asked New England's transmission owners and developers to identify proposed projects through which the states could endeavor to implement some coordination mechanisms achievable in the near-term.[11] This effort is not limited to transmission projects to reach renewable resources but should be helpful to them.

In mid-2011, the New England Governors expressed by Resolution their continued interest in exploring the potential for coordinating competitive renewable power procurement as

[8] The Report is available at this link: http://www.nescoe.com/uploads/Report_to_the_Governors_July_2010.pdf
[9] Generation responses to the RFI are summarized at this link: http://www.nescoe.com/uploads/Prelim_RFI_Results_For_Release.pdf
[10] Transmission responses to the RFI are summarized at this link: http://www.nescoe.com/uploads/Summary_of_SIF_Responses_final.pdf
[11] Notice of the Siting Collaborative is at this link: http://www.nescoe.com/uploads/Interstate_Siting_Collaborative.pdf

a means to identify the resources that could help meet regional renewable energy goals at the lowest "all-in" cost.[12]

V. GENERATION SUPPLY CURVE ANALYSIS: WIND RESOURCES IN NEW ENGLAND & NEW YORK

To provide additional information to help inform regional policy makers about possible ways forward to meeting the states' renewable energy goals, NESCOE requested SEA to: 1) provide indicative analyses of the potential for developing new on-and off-shore wind resources in New England and New York; and, 2) estimate the relative "generation only" costs of such resources under a specific set of cost assumptions. NESCOE also requested RLC Engineering to provide indicative, high-level cost estimates associated with representative transmission development scenarios that could facilitate the delivery of energy from new wind generation located in northern New England.

A. Summary of SEA Wind Generation Analysis

NESCOE requested SEA to estimate the total wind generation that could be developed in New England by 2016 and by 2020, and the total on-shore wind generation that could be developed in New York by 2020. To develop these estimates, SEA divided the New England and New York wind resources into "supply blocks".[13] For each supply block, SEA calculated values that it used to analyze the availability and cost of wind energy from various resources in that supply block. These included:

- The total capacity in MWs and annual energy in GWh/yr that could be placed into operation by 2016 and by 2020; and,

[12] The New England Governors' Conference Resolution is at this link: http://www.nescoe.com/uploads/NEGC_Coord_Procure_Res._.pdf

[13] A *supply block* is a single block of potential wind generation that was separately identified by SEA. Each supply block has a specified (i) project type ('small', 'medium' or 'large' for on-shore wind projects, and 'shallow' or 'deepwater' for off-shore wind projects), (ii) wind speed regime, (iii) generation costs and transmission interconnection costs and (iv) other attributes of that resource block (*e.g.,* ultimate wind generation capacity and maximum buildout rates).

- The *Levelized Cost of Electricity* ("LCOE"). The LCOE is a single, fixed levelized price that would be paid under a long-term contract by a purchaser of all of the electrical output and environmental attributes produced from a wind project in the specific supply block over the specified term of the contract.[14] SEA computed the LCOE for two in-service dates (2016 and 2020) and for three contract terms (10, 15 and 20 years), leading to six LCOEs for each supply block.

SEA's analyses ultimately consisted of resource potential and cost information on 141 supply blocks in New England and 41 on-shore wind supply blocks in New York.[15]

B. New England and New York Regional Wind Potential

The wind resources that could be developed in New England and New York in the study years greatly exceed the region's needs. The following three tables show regional wind potential by 2016, and 2020 and then compares it to the region's renewable energy needs. In sum, by 2016, the region could develop 8,012 MW of wind. By 2020, the region could develop 34,596 MW. The resources could supply 21,245 and 118,227 GWh/yr in 2016 and 2020, respectively, versus an expected regional need of 7,500 and 12,250 GWh/yr, respectively.

[14] The LCOE is calculated to meet the minimum investment criteria of the project's debt and equity investors, and represents the lowest contract price at which wind projects within the supply block are economically feasible

[15] For New York wind resources, SEA only considered one study year (2020) and one contract term (15 years).

Table 1 summarizes the total MWs and annual energy that could be developed by 2016.

TABLE 1

TOTAL REGIONAL WIND POTENTIAL BY 2016

State	On-shore wind		Off-shore wind		Total	
	MWs	GWh/yr	MWs	GWh/yr	MWs	GWh/yr
CT	3.8	9	139.0	426	142.8	435
MA	137.3	366	938.9	3,500	1,076.2	3,865
ME	4,925.4	11,000	975.4	3,490	5,900.8	14,490
NH	304.4	758	0.0	0	304.4	758
RI	0.0	0	180.3	644	180.3	644
VT	408.0	1,053	0.0	0	408.0	1,053
NE total	**5,779.0**	**13,185**	**2,233.6**	**8,060**	**8,012.6**	**21,245**
NY (not calculated for 2016)	0.0	0	0.0	0	0.0	0
Grand total	**5,779.0**	**13,185**	**2,233.6**	**8,060**	**8,012.6**	**21,245**

Table 2 summarizes the wind resources that could be developed by 2020.

TABLE 2

TOTAL REGIONAL WIND POTENTIAL BY 2020

State	On-shore wind		Off-shore wind		Total	
	MWs	GWh/yr	MWs	GWh/yr	MWs	GWh/yr
CT	6.6	15	374.9	1,144	381.5	1,159
MA	460.7	1,208	10,974.5	44,354	11,435.3	45,562
ME	8,963.8	20,165	9,587.7	38,404	18,551.5	58,568
NH	582.8	1,459	0.0	0	582.8	1,459
RI	0.0	0	1,499.7	5,998	1,499.7	5,998
VT	1,156.0	2,993	0.0	0	1,156.0	2,993
NE total	**11,169.9**	**25,839**	**22,436.8**	**89,900**	**33,606.7**	**115,739**
NY[16]	989.9	2,488	0.0	0	989.9	2,488
Grand total	**12,159.7**	**28,327**	**22,436.8**	**89,900**	**34,596.6**	**118,227**

16 Although SEA considered the total developable on-shore wind resources in NY, the resources available to New England were constrained in subsequent analyses to approximately 1000 MW or less, in recognition of likely limits on available transmission capability between New York and New England.

Table 3 compares these potential resources to estimated regional needs[17] in 2016 and 2020. The table shows that the regional potential greatly exceeds the expected regional needs.

TABLE 3
COMPARISON OF REGIONAL LOADS, RENEWABLE ENERGY NEEDS, AND POTENTIAL WIND RESOURCES

	2016	2020
Total New England energy demand, net of energy efficiency & passive demand resources (GWh/year)	129,444	127,098
Total incremental renewable energy needed (GWh/yr)	7,500	12,250
Total wind potential (GWh/year), by source		
New England (on-shore)	13,185	25,839
New England (off-shore)	8,060	89,900
New England (total)	**21,245**	**115,739**
Imports from New York (imports in 2016 not considered but may be possible)	0	2,488
Grand total	**21,245**	**118,227**

C. Range of Wind Costs & Implications of Conservative Assumptions

The regional wind energy resources able to be developed by 2016 and 2020, in Tables 1 through 3 above, have a very wide range of capital costs and expected energy output. Consequently, the LCOEs for those resources also have a very wide range – from \$95/MWh to \$415/MWh.

These costs reflect conservative assumptions, including:

- *No* federal financial incentives for any future wind projects;
- Interest rates consistent with *normal economic growth*; and,

17 In this context, "regional needs" are the estimated *incremental* renewable energy required to meet New England's renewable energy goals by the specified year, based on projected total regional demand and the contributions of renewable resources either in operation or firmly under development.

- The use of *traditional hub heights* for on-shore wind projects.

Changing *any* of these assumptions to be less conservative could materially decrease the expected LCOEs. Since several conservative assumptions were simultaneously used in developing the base case LCOEs, the actual costs for specific projects are likely to be significantly less than the base case values. As noted later, the potential decreases in the LCOE could range from $33 per MWh to $68 / MWh, with greater decreases for on-shore generation projects that could use taller towers.

D. 2016 & 2020 Supply Curves & Implications of Different Contract Terms & Assumptions

Figures 1 and 2 below show the supply curves for New England's[18] wind resources for 2016 and 2020, respectively.[19] Each figure shows three supply curves, one curve for each of the three contract terms - 10, 15 and 20 years.

[18] The cost of New York wind resources was only developed for a 15-year contract term. Thus, for consistency, the potential contribution of New York resources to meeting regional renewable energy goals was omitted from these figures.

[19] To construct a regional supply curve, NESCOE "stacked" the supply blocks in order of increasing LCOE. NESCOE also plotted the price of the 'marginal' supply block against the cumulative amount of annual wind generation.

FIGURE 1 - 2016

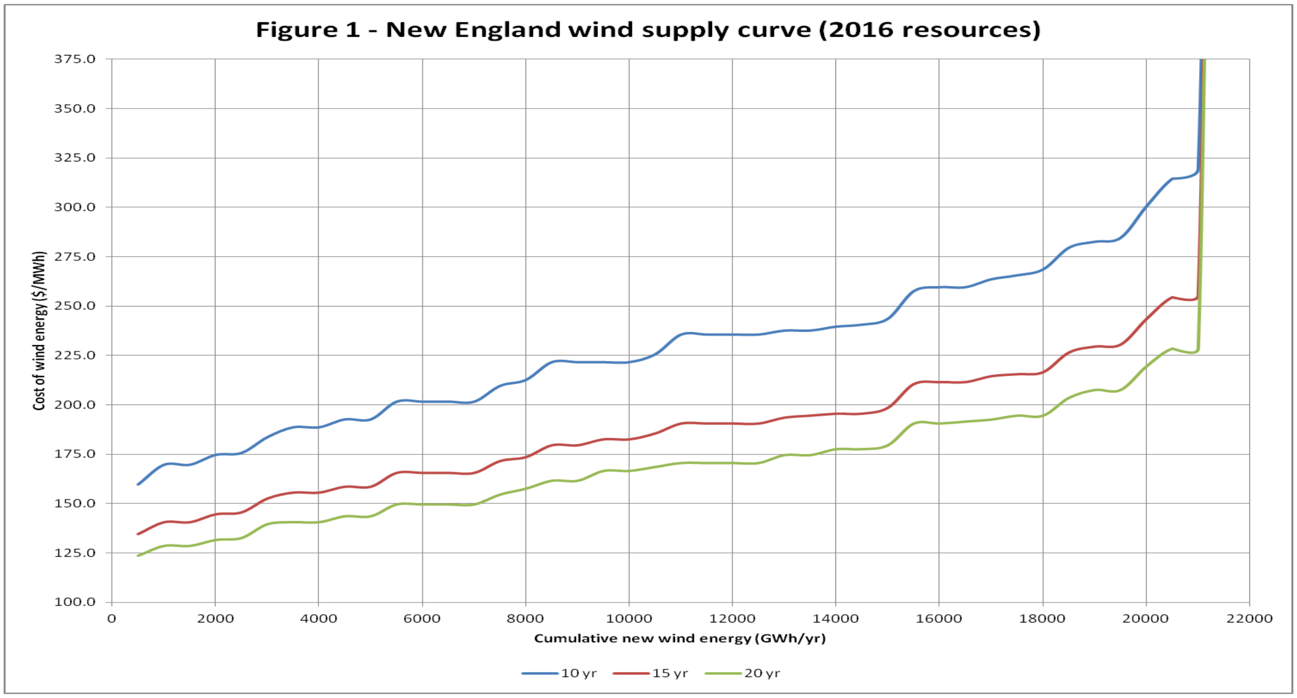
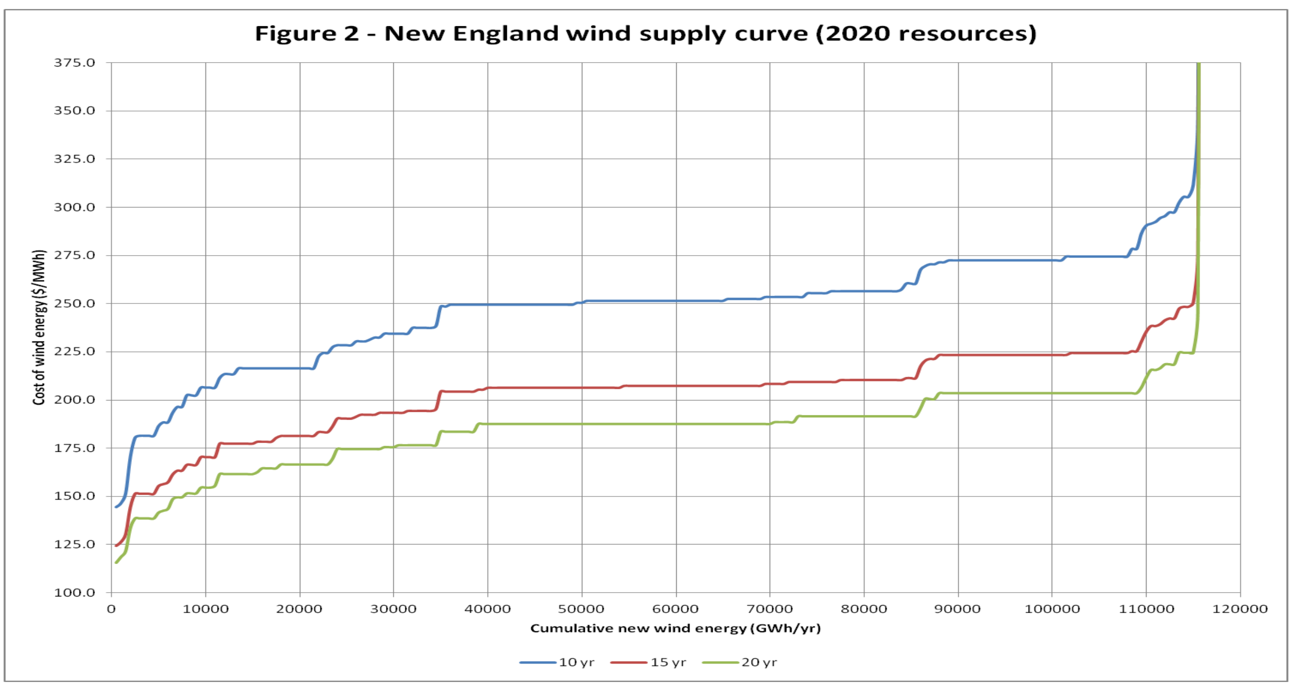


FIGURE 2 - 2020



Observations

- The left side of the supply curves shows how the cost of the "last resource added" increases as the total annual wind generation increases.
- Further to the right, the supply curves are relatively flat over large ranges of annual energy production. At certain threshold prices, very large wind energy resources become economically feasible. For example, under a 20-year contract starting in 2016, large on-shore wind projects in Maine with low wind speeds have an LCOE of $149.5/MWh. These wind resources could produce over 1500 GWh/year at this price. Thus, these resources "flatten" the 2016 supply curve (assuming a 20-year contract) between 5500 GWh/year and 7000 GWh/year.

Changed Contract Term Implications

Contract term has a material impact on the LCOE. Shorter contract terms lead to higher LCOEs. Table 4 shows the approximate savings associated with 15 and 20 years contract terms in relation to a 10-year term:

Table 4

Comparison of LCOEs for Different Contract Terms

Contract term	**Notional LCOE**	**Savings vs. 10 year contract term**
10 years	$200 / MWh	-
15 years	$165 / MWh	17.5%
20 years	$150 / MWh	25%

Cost Implications of Using Less Conservative Assumptions

As noted, SEA's analysis is based on conservative assumptions. There is no way to predict with precision what assumptions may prove to be right or wrong over time: neither NESCOE nor SEA know with certainty whether Congress may extend federal financial incentives, what may happen to interest rates, or the extent to which individual on-shore generation project may benefit from the use of taller towers. For illustrative purposes, SEA also estimated the impacts of changing the conservative assumptions used in the supply curves

(shown in Figures 1 and 2, above). Table 5 below shows the typical reductions in LCOE that could occur under different assumptions, assuming a 15-year contract term:[20]

Table 5

Typical Reduction in LCOE from Less Conservative Assumptions

Change in assumption	Typical reduction in LCOE under 15 year contract
Federal financial incentives extended indefinitely	\$23 / MWh reduction
Current economic climate of low interest rates continues indefinitely	\$10 / MWh reduction
On-shore projects use higher hub heights to achieve higher capacity factors	\$35 / MWh reduction
Range of cumulative reductions possible	\$33 / MWh for all projects \$68 / MWh for on-shore projects that can use taller towers

E. Contributions of Different Types of Wind Resources

The supply curves shows in Figures 1 and 2, above, do not show the *types* of wind resources that comprise the overall regional resource base. To illustrate the mix of various wind resources, NESCOE created a single supply curve for each study year that shows the contribution of five types of wind resources. These supply curves also assume a 15-year contract term in the years 2016 and 2020.

The five types of wind resources included:

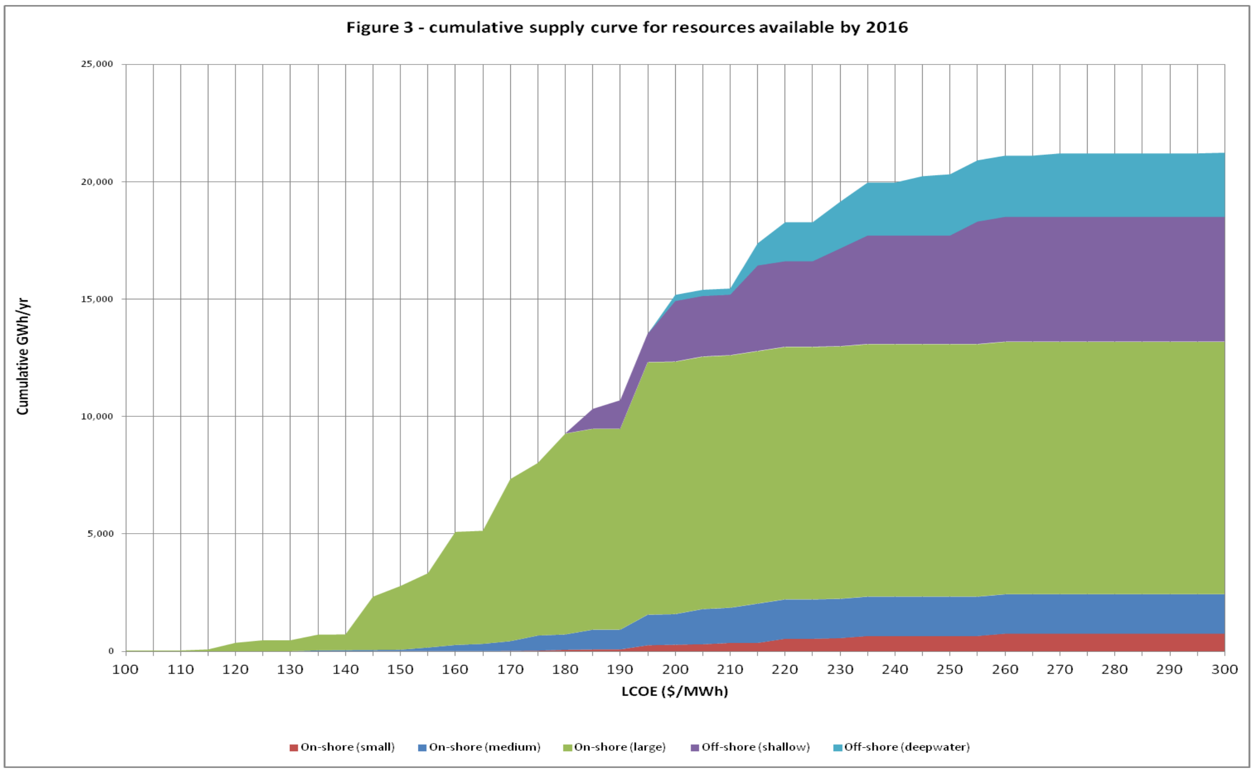
1. On-shore wind, small scale projects – typical project size is 10 MW
2. On-shore wind, medium scale projects – typical project size is 60 MW
3. On-shore wind, large scale projects – typical project size is 125 MW

[20] Section 5 of New England Wind Generation Report by SEA describes these sensitivity analyses is more detail.

4. Off-shore wind in shallow (< 30 m) water – typical project size is 300 MW
5. Off-shore wind in deep (> 30 m) water – typical project size is 300 MW

FIGURE 3

THE "STACKED" SUPPLY CURVE FOR 2016



ANOTHER VIEW OF 2016

FIGURE 3A

Slide Courtesy, Sustainable Energy Advantage, LLC
based on conservative assumptions discussed in this Report

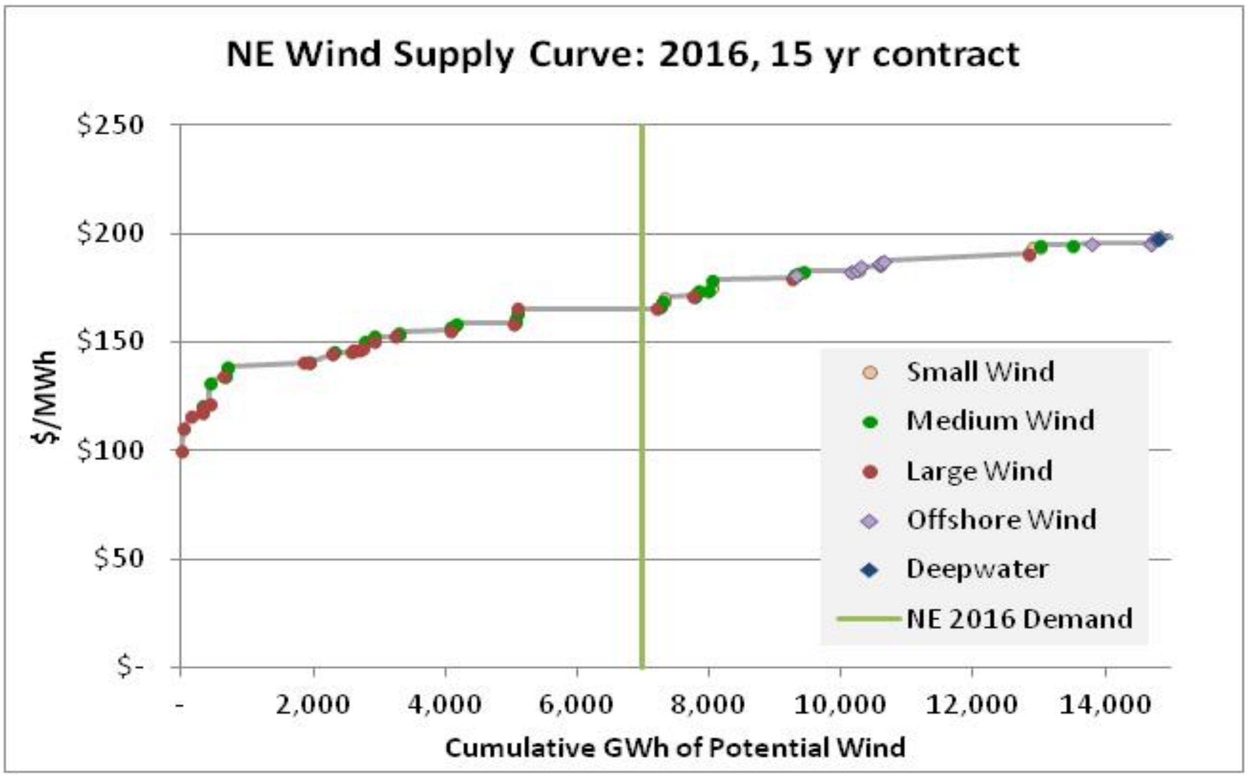
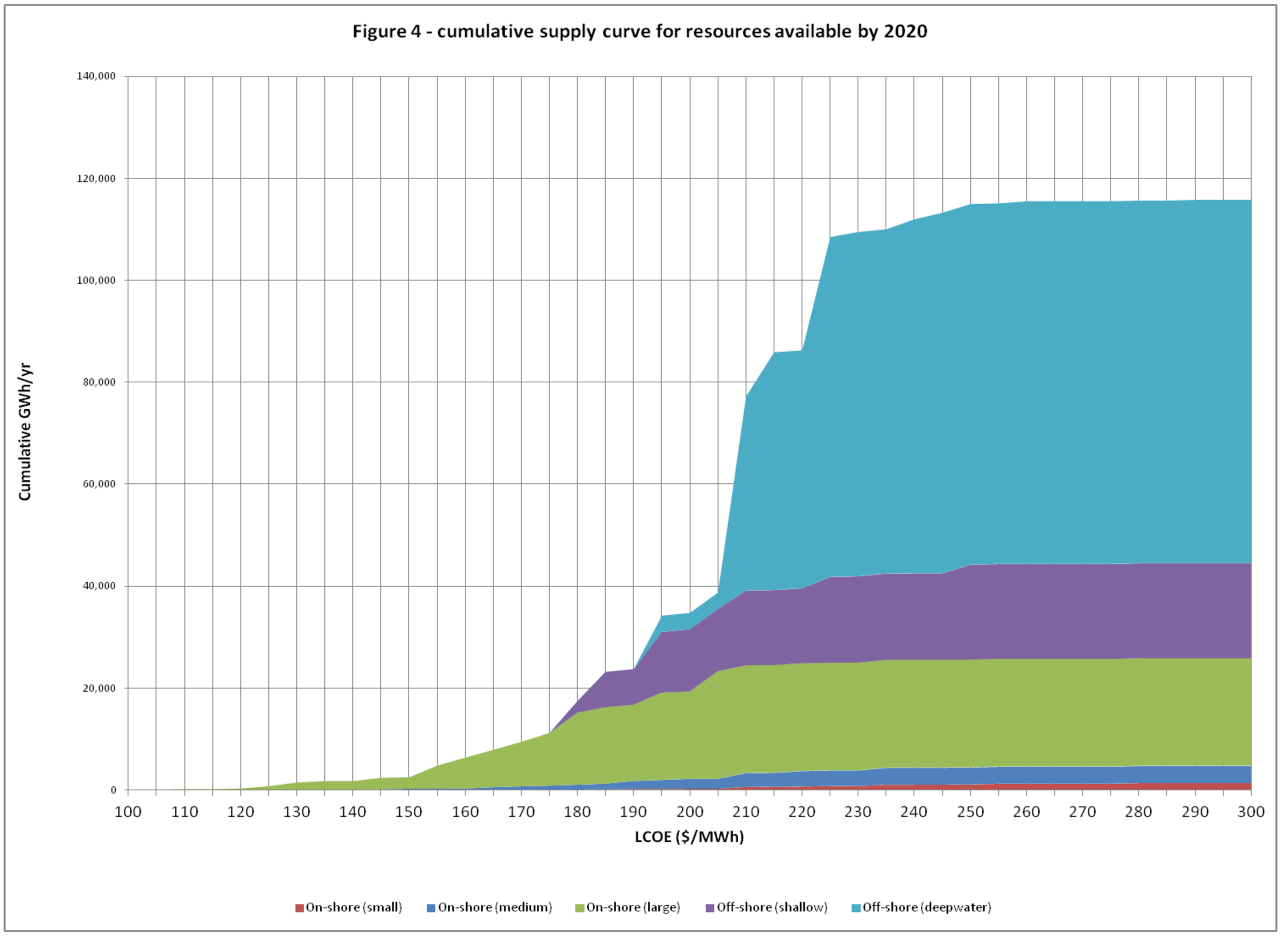


FIGURE 4

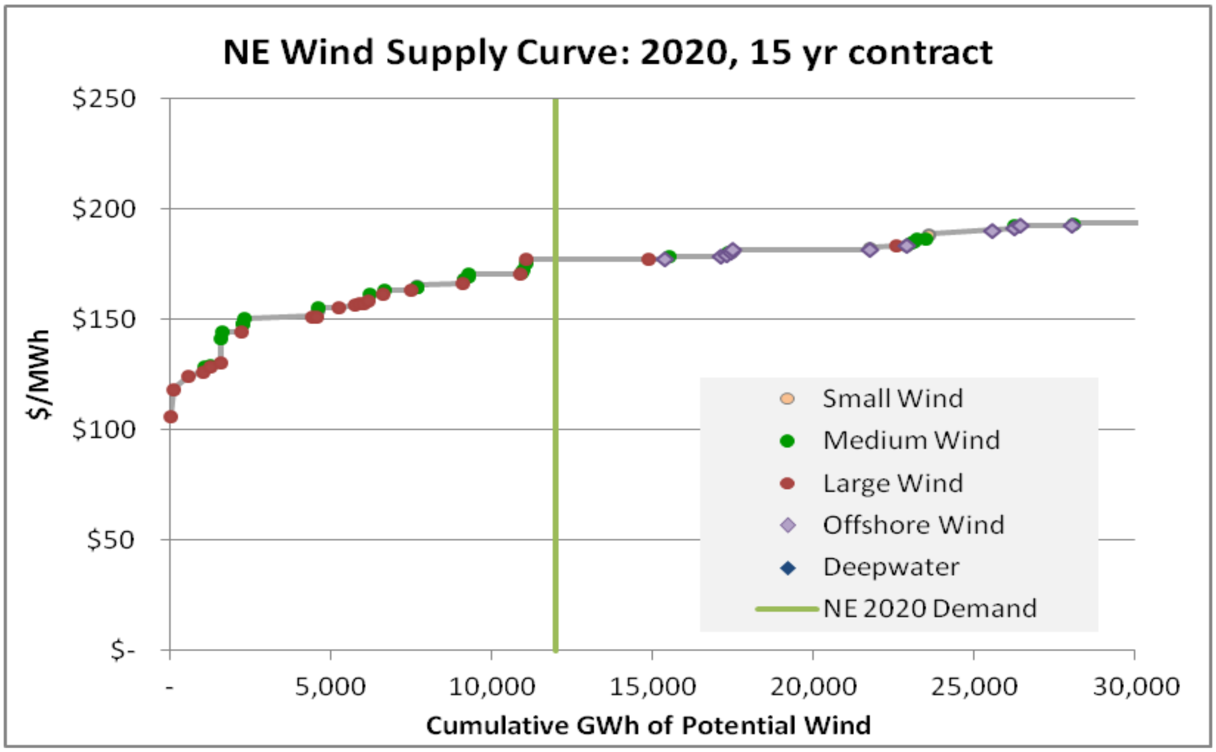
THE SUPPLY CURVE FOR 2020



ANOTHER VIEW OF 2020

FIGURE 4A

Slide, Courtesy Sustainable Energy Advantage, LLC
based on conservative assumptions discussed in Report



Observations

- Through 2016, large-scale on-shore wind dominates the supply curve through about 10,000 GWh/year. At that point, some off-shore resources become economically feasible. Small and medium scale on-shore resources make minor contributions.
- By 2020, very large amounts of off-shore wind, particularly deep water resources, become technically available, and are economically feasible at approximately $210 / MWh.

F. The Least Expensive Mix of Wind Resources in 2016 & 2020 When Considering *Only* SEA's Generation Costs

As the information in Figures 3 and 4 above makes clear, the region has a mix of wind resources - and associated ranges of costs - over a very large range of annual energy production. To better understand the mix of resources that may be most likely to help meet the region's renewable energy needs at the lowest cost, NESCOE more closely scrutinized the left side, or lower portions, of the supply curves.

The analysis identified resources by location (on-or off-shore) and by state:

- That could provide 7500 GWh/year - the estimated regional need in 2016 - at the lowest cost in 2016.
- That could provide 12,250 GWh/year - the estimated regional need in 2020 - at the lowest cost in 2020.

Additionally, imports from New York up to 1000 MW, corresponding to maximum energy imports of approximately 2500 GWh / year, were considered in the supply mix.[21]

Table 6 below shows the least expensive resources required to meet regional needs in 2016 and in 2020 when considering *only* SEA's generation costs.

[21] SEA's estimates of potential wind resources in NY only reflected resources available by 2020. For purposes of this analysis, up to 35% of the potential 2020 resources were assumed to be potentially available in 2016.

TABLE 6
MIX OF WIND RESOURCE REQUIRED TO MEET REGIONAL NEEDS IN 2016 & 2020 AT LOWEST LCOE
LEAST GENERATION-ONLY COST

	Mix of wind resources for 2016 (GWh/yr)			Mix of wind resources for 2020 (GWh/yr)		
	Only generation costs considered			Only generation costs considered		
	On-shore	Off-shore	Total	On-shore	Off-shore	Total
CT	0	0	0	0	0	0
MA	346	0	346	936	0	936
ME	5,391	0	5,391	5,743	0	5,743
NH	309	0	309	595	0	595
RI	0	0	0	0	0	0
VT	883	0	883	2,489	0	2,489
New England total	6,929	0	6,929	9,762	0	9,762
NY	571	0	571	2,488	0	2,488
Grand total	7,500	0	7,500	12,250	0	12,250

Observations

- On-shore wind in Maine dominates the supply mix in 2016. It constitutes 72% of the most economical energy available in that year.
- In 2020, on-shore generation in Maine still constitutes 47% of the most economical energy, with increasing contributions by imports from New York.
- If *only* generation costs are considered, on-shore wind resources in Maine, Vermont and New Hampshire would constitute the majority of the most economical energy, with growing contributions from imports from New York. These findings are consistent with the results of NESCOE's RFI. The RFI responses suggested a concentrated interest in wind resources in northern New England and particularly in Maine.

VI. TRANSMISSION TO SUPPORT ADDING LARGE AMOUNTS OF WIND TO NORTHERN NEW ENGLAND

Whether the wind resources identified above in Table 6 as able to be developed at the lowest generation cost would serve customers at the lowest "*all-in*" cost – the cost of generation and transmission combined – depends on whether the *existing* transmission system in New England could effectively integrate the energy from those wind resources or whether new transmission would be required to integrate that energy into the regional power supply mix (and the cost of such new transmission).

For that reason, NESCOE requested that RLC: 1) examine the ability of the existing transmission system to support the addition of large amounts of wind generation in northern New Hampshire and western Maine; and, 2) to the extent that new transmission facilities would be required to add such generation, identify potential upgrades that could do so; and 3) develop estimated costs and schedules for developing such upgrades.

RLC concluded that significant new transmission would be required to add large amounts of incremental wind generation in those regions. Table 7, below, summarizes RLC's key findings regarding the upgrades required to integrate large amount of wind generation in these regions.

TABLE 7

KEY RESULTS FROM RLC TRANSMISSION ANALYSES[22]

			Maximum cumulative wind generation integrated		
State	Upgrade	Earliest year of initial operation	MWs	GWh/yr	Cost of required upgrades ($/MWh of wind energy)
NH	Upgrade NH1	2016	300	788	44
ME	Upgrade ME1	2016	1123	2,951	35
ME	Upgrade ME2	2020	2123	5,579	35

RLC's analysis indicated that the single transmission upgrade identified for New Hampshire could integrate enough wind energy to support the low-cost wind in that state.[23] However, the amounts of on-shore wind generation in Maine - suggested in Table 6 as low-cost

[22] Considerations about the key results from RLC transmission analyses (Table 5):

- RLC identified seven sets of upgrades in New Hampshire and Maine, developable over several years, which could interconnect up to 3,123 MW of wind generation. For purposes of this analysis, the most expensive and least necessary upgrade was discarded. The remaining six upgrades were condensed into the three upgrades – NH1, ME1 and ME2 – shown above.
- The suggested upgrades in Maine would allow wind energy from the Wyman and Rumford regions to be delivered to the existing 345 kV transmission system in the coastal Maine region. However, additional upgrades (*e.g.,* an HVDC submarine cable between coastal Maine and load centers in Massachusetts with a capacity of 600 to 800 MW and a unit cost of circa $60 / MWh) may be required to effectively displace high-cost generation in the southern New England region. For this analysis, such additional "deep" network upgrades were assumed *not* to be necessary and were not considered further.

[23] The maximum desired wind generation from New Hampshire of 595 GWh/year show in Table 6 is less than the 788 GWh/year that could be supported by the indicated upgrade

- exceeds the transmission system capacity that could be developed by 2016 and 2020. Table 8, below, compares the low cost resources in New Hampshire and Maine to what RLC concludes the New England transmission system could handle with the identified transmission upgrades.

TABLE 8
ANNUAL WIND ENERGY FROM NEW HAMPSHIRE & MAINE – COMPARISON OF LOWEST GENERATION-ONLY COST RESOURCES (TABLE 6) TO TRANSMISSION ANALYSES

	Energy by 2016 (GWh/yr)			Energy by 2020 (GWh/yr)		
State	Suggested by Table 6	Feasible per RLC analysis	Need to constrain?	Suggested by Table 6	Feasible per RLC analysis	Need to constrain?
NH	309	788	No	595	788	No
ME	5,391	2,951	**Yes**	5,743	5,579	**Yes**

It may be appropriate to allocate some of the transmission system upgrade costs to the wind resources in northern New England that cause the need for such upgrades. Allocating the costs of that transmission to those wind resources would increase their "all-in" costs relative to wind resources that may not require new transmission. This, in turn, may reduce the total amount of generation from northern New England that is included in the "least all-in cost" supply mix.

To test the impact of the limits to and cost of developing transmission upgrades in northern New England, NESCOE performed a sensitivity analysis in which:

- The cost of on-shore wind generation in Maine and New Hampshire[24] was increased by 50% of the transmission system upgrade costs (expressed in \$/MWh) suggested by the RLC analyses; and

24 Although no transmission analyses were performed regarding the need for and cost of transmission upgrades required to integrate on-shore wind generation in VT, this sensitivity analysis also increased the cost of on-shore generation in VT by the same amount as the increase in the cost of on-shore generation in NH, on the assumption that significant wind generation in VT would also require network upgrades with similar costs.

- As necessary, on-shore wind generation in Maine was constrained to the limits shown in Table 7.

Specifically, NESCOE: 1) increased the LCOEs for on-shore wind generation in Maine, New Hampshire and Vermont; 2) constrained on-shore wind generation in Maine as necessary; and 3) "restacked" the wind energy supply blocks, to identify a revised least cost supply mix that reflects transmission costs ("least all-in costs"). Table 9 shows the resulting supply mixes for 2016 and 2020.

TABLE 9
MIX OF WIND RESOURCE REQUIRED TO MEET REGIONAL NEEDS IN 2016 & 2020 AT LOWEST "ALL-IN" LCOE

	Mix of wind resources for 2016 (GWh/yr)			Mix of wind resources for 2020 (GWh/yr)		
	Apply 50% of network upgrade costs to on-shore wind in ME, NH and VT, and constrain on-shore generation in ME			Apply 50% of network upgrade costs to on-shore wind in ME, NH and VT, and constrain on-shore generation in ME		
	On-shore	Off-shore	Total	On-shore	Off-shore	Total
CT	0	0	0	0	0	0
MA	360	720	1,080	986	2,683	3,669
ME	2,711	59	2,770	3,949	206	4,155
NH	280	0	280	396	0	396
RI	0	0	0	0	76	76
VT	883	0	883	1,467	0	1,467
New England total	4,233	779	5,012	6,798	2,964	9,762
NY	2,488	0	2,488	2,488	0	2,488
Grand total	6,721	779	7,500	9,286	2,964	12,250

Observations About the Least "Generation-Only" Cost Resources (Table 6) & Least "All-In" Cost Resources (Table 9)

- If the cost of on-shore generation in Maine, New Hampshire and Vermont is increased (and on-shore generation in Maine is constrained to maximum levels indicated by RLC's transmission analyses), then a larger percentage of regional needs might be supplied from off-shore wind and imports. In 2016, imports and off-shore wind would provide 44% of total regional needs (vs. 8% from Table 6/least generation-only cost). The corresponding values for 2020 are 45% (from Table 9) vs. 20% (from Table 6/least generation–only cost)
- Imports from New York, which are assumed *not* to require significant transmission network upgrades, are at the maximum allowed values of 1000 MW in 2016 and 2020.[25] By 2020 and to some extent even by 2016, off-shore wind becomes the marginal wind resource. Given the large quantities of off-shore wind energy available at relatively flat costs and the projected decreases in the cost for off-shore wind, it may be reasonable to expect that off-shore wind could eventually increase its share of the region's renewable energy mix.[26]

However, observations about the least "all-in" cost resources (Table 9) compared to least generation–only cost (Table 6), are based on assumptions, which may or may not prove accurate. First, the observations assume that the existing transmission system cannot support meaningful additional wind generation in Maine, New Hampshire and Vermont. If the existing system could support additional on-shore wind generation, the amount of economical on-shore wind generation in these states would be greater than what is shown in Table 9.

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25 If wind imports could use a higher fraction of the existing transmission capacity, or if wind imports from other adjacent control areas were considered, an even greater percentage of regional needs could be met by such imports.

26 One of the most significant findings in Table 9 is that while the economically feasible on-shore generation from ME in 2016 is close to the limits suggested by RLC's analyses (2711 GWh/yr vs. a maximum of 2951 GWh/yr), by 2020, on-shore generation in ME is limited by costs, not transmission buildout constraints (*e.g.,* the annual energy production of 3949 GWh/yr in Table 9 is significantly less than the maximum limit of 5579 GWh/yr) suggested by the transmission analyses.

Second, the observations assume that the generation cost premium for off-shore wind decreases as SEA forecasts.[27] Such cost decreases may or may not happen.

Third, the base case LCOEs for on-shore wind projects were developed using historical hub heights (80 meters). Many wind developers in the region are planning to use taller towers that could achieve higher capacity factors, allowing a corresponding decrease in the cost of on-shore wind energy. If enough on-shore wind projects can employ taller towers that achieve higher capacity factors, then on-shore wind projects may provide almost all of the competitive wind resources.

Finally, the observations assume that the incremental transmission required to effectively integrate new *off-shore* wind generation and wind imports is significantly less than the incremental transmission required to integrate new *on-shore* wind generation in northern New England. Off-shore wind generation and wind imports may be able to displace fossil generation with relatively few, if any, transmission upgrades (*e.g.,* by directly interconnecting at an existing coastal fossil generating station). However, such an integration standard could limit the market benefits of those wind resources because they may not be able to displace the highest cost generation or contribute towards regional reliability goals. Adopting a different integration standard, discussed further below, could significantly affect the transmission required by different wind resources and thus materially change the mix of resources with the lowest "all in" costs.

VII. OPTIONS FOR INTEGRATING WIND ENERGY INTO THE REGIONAL TRANSMISSION SYSTEM

This analysis highlights the importance of the preferred level of 'integration' for incremental wind energy. The standard for wind energy integration determines the timing, magnitude and costs of the transmission upgrades required for specific new wind resources. How the

[27] SEA forecasts that the unit installed cost for off-shore wind will *decrease* by about 1.4% per year. SEA forecasts that the unit installed cost of on-shore wind will *increase* by approximately 1.7% per year. If the resulting decrease for off-shore wind does not happen, then on-shore wind could continue to dominate the region's least cost mix of wind resources.

transmission costs are allocated will, in turn, affect the relative cost-competitiveness of different wind resources.

The results of these analyses and the existing ISO-NE interconnection processes and standards suggests two potential integration standards: a minimum "REC Only" standard, and a more stringent "REC Plus" standard.

> *"REC Only Integration"* – Under this standard, new wind generation would simply need to displace non-renewable energy resources and thus contribute to regional renewable energy goals. For example, an off-shore wind project that connects directly to the switchyard of an existing fossil-fueled generating station may be able to displace one MWh of fossil generation for each MWh of wind generation, without requiring any additional transmission beyond the interconnecting switchyard. Similarly, a remote on-shore wind project could displace nearby gas-fired generation on a MWh-for-MWh basis, with minimal network upgrades. New wind resources integrated under this standard would contribute to regional renewable energy goals, but may not provide the resource's full benefits in the region's commodity markets, such as reductions in capacity and energy prices. Some other considerations related to this option are that it could result in energy market congestion with low priced energy bottled up in Maine and New Hampshire and it may lead to increased uplift as more localized operating reserves could be required.

> *"REC Plus Integration"* – Under this standard, new renewable energy resources would need to be more integrated into the regional power supply system. As one example of a REC Plus standard, some specified percentage of incremental wind generation would have to be deemed 'deliverable' to major load centers in New England. An alternative version of a REC Plus standard would required that new wind resources be fully integrated into the region's capacity market, and thus contribute to the region's installed capacity requirements.

> A REC Plus standard would allow new wind resources to produce larger benefits in the region's commodity markets, but would require additional transmission capacity and associated costs.[28]

New England's current interconnection process, which considers generation projects serially rather than in groups, would not support an efficient coordinated renewable procurement process that used a REC Plus integration standard. Selection of a REC Plus standard would likely require significant changes to the interconnection queue process to enable ISO-NE to study generation projects in clusters before one or more states could undertake to conduct an efficient competitive coordinated renewable procurement process. It is possible that the REC Only integration standard may allow the efficient development and implementation of a competitive coordinated renewable procurement process without extensive changes to the current interconnection process.

[28] In theory, determining the optimal level of integration for any particular project would require comparing the incremental transmission costs required to achieve any particular level of integration with the incremental market benefits obtained from that level of integration. Standard economic theory would suggest that for each project, the optimal level of integration would be the point at which the incremental transmission cost of additional integration exactly equaled the incremental market benefits of additional integration.

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